REPORT No. 32

THE AIRPLANE TENSIOMETER

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

PREPRINT FROM FOURTH ANNUAL REPORT

▽

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

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THE AIRPLANE TENSIOMETER.

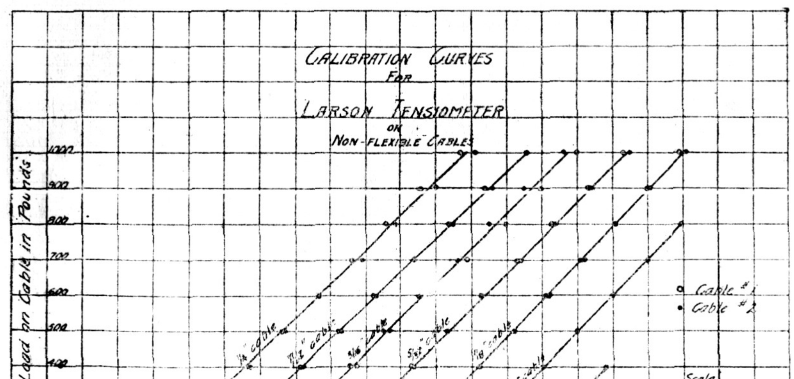
By L. J. LARSON.

Light weight is an essential factor in the design of modern airplanes, especially those for military purposes, for which speed and maneuvering ability are of great importance. With the best grade of materials and careful designing the light weight desired can be obtained, but only by not using an excessive factor of safety. Under such conditions accidental or careless overloading of the airplane members must be avoided.

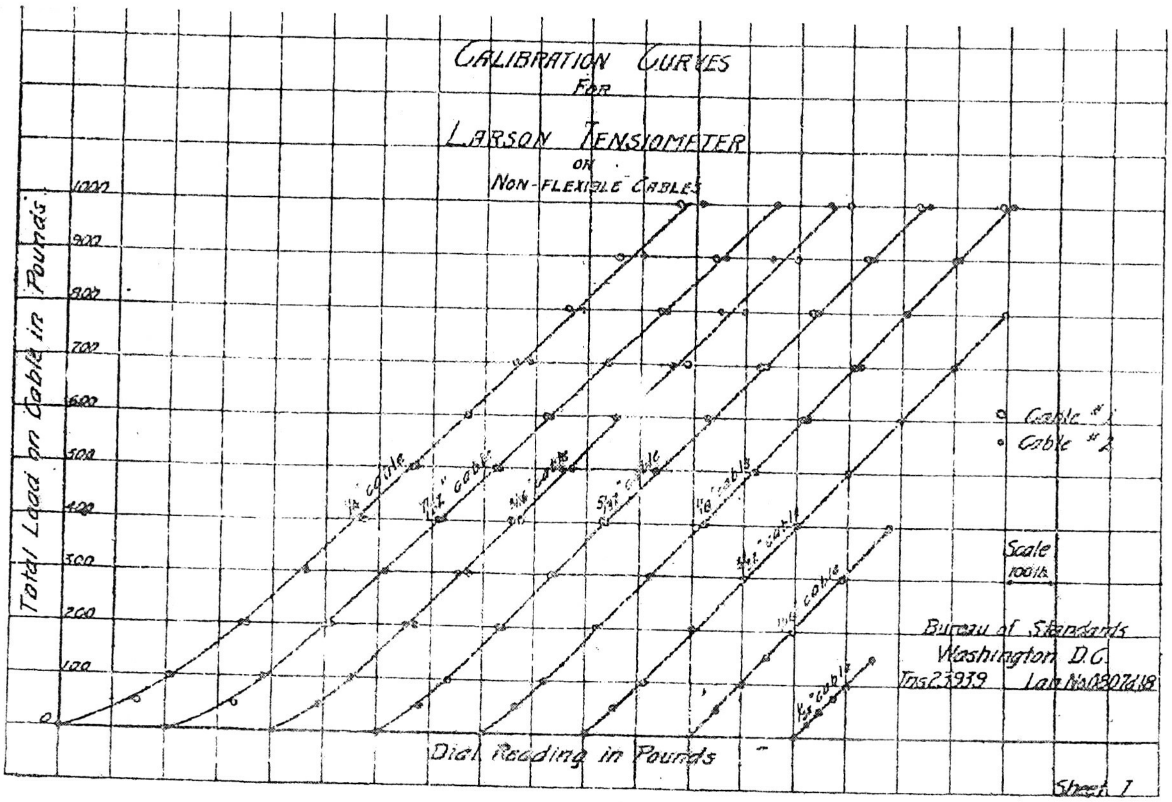
Certain parts of an airplane are subjected not only to the stresses imposed by the aerodynamic or flying load, but also to the initial stresses, caused by the tension in the stay and drift wires. An appreciable initial stress in these wires is necessary to maintain the alignment of the machine. In many cases the initial stresses have been found to form too large a proportion of the total load. Failure of the structure in service has resulted from an improper adjustment of the turnbuckles in the stay and drift wires and cables.

It has been customary to depend upon the judgment of the mechanics assembling an airplane for securing the correct initial tension through adjustment of the turnbuckles. They secured what they considered the proper uniform tension by the "feel" of the wire or by listening to its vibrant sound when plucked with the finger. Either of these methods is obviously crude and inaccurate, owing, among other things, to the widely varying diameter and length of the wires. Some experiments have shown that wires thus adjusted for equal tension have really varied by several hundred per cent. A dangerous condition may thus be developed by causing overloading of airplane members through adjustment of initial tension. This emphasizes the need of an apparatus to determine accurately the load in a flexible tensile member.

Several instruments for this purpose have been devised, but most of them are inaccurate, cumbersome, or require the services of an experienced person for their successful use. The Tensiometer, on the other hand, is simple in construction, accurate, and easily and quickly operated even by inexperienced persons.



Two sizes of the instrument are shown in figure 1. One is suitable for wires up to one-fourth inch in diameter and the other for wires from one-fourth to three-eighths inch in diameter.



CALIBRATION CURVES
FOR
LARSON TENSIOMETER
ON
NON-FLEXIBLE CABLES
Total Load on Cable in Pounds
Dial Reading in Pounds
Cable #1
Cable #2
Scale
100 lb.
Bureau of Standards
Washington D.C.
Tns23939
Lab No.0807d.18
Sheet 1

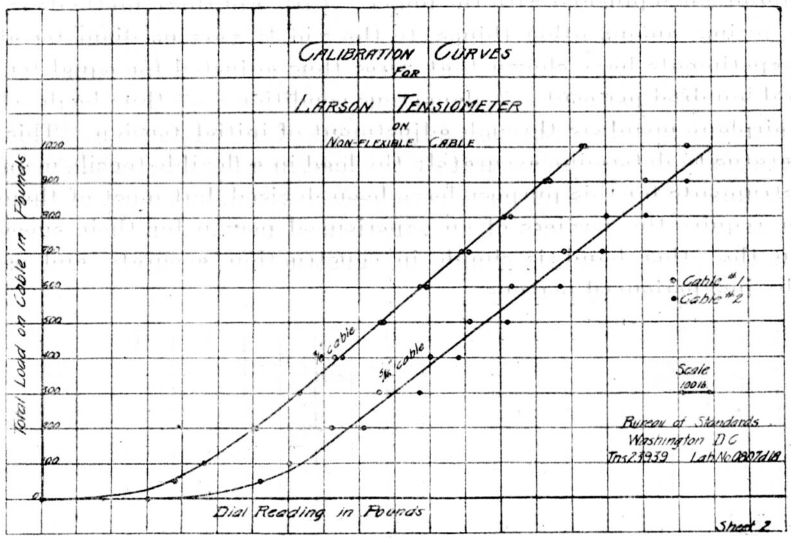
Fig 1

The instrument consists essentially of a frame with supports spaced 10 inches apart, between which a section of the wire or cable is adjusted. Midway between these supports, and operated by hand grips, is a plunger which deflects the wire 0.1 inch from its normal position. The operation of deflecting the wire compresses a calibrated spring. A dial indicator measures the deformation of the spring and thus the load on the wire. One revolution of the indicator pointer corresponds to a load of 1,000 pounds, and the smallest dial division, to a 10-pound load.

The Tensiometer is made direct reading by graduating the indicator dial upon the loading spring so as to read tension in the wire instead of load upon the spring. A second dial indicator allows the simultaneous determination of the deflection to the nearest 0.001 inch. The use of these two sensitive indicators for accurately determining the position and load upon the wire is, in a great measure, the reason why accurate results are obtained with the Tensiometer.

The theory upon which the instrument is based is very simple. If a wire, under tensile stress, is supported at two points and loaded at the middle of the span thus formed, a system of three forces in equilibrium is established. If the span and deflection are kept constant, as in this instrument, the deflecting force is a constant fraction of the tension in the wire.

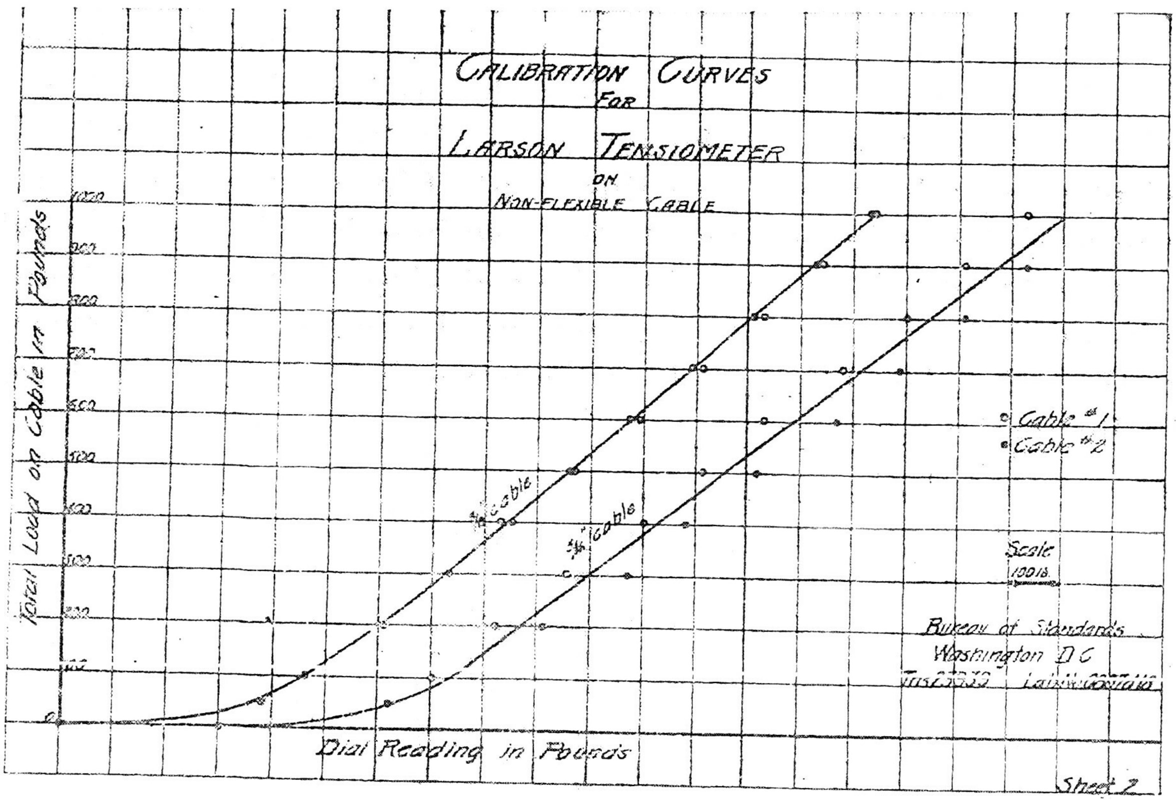
In use it is never desirable to attach the Tensiometer to the wire. It is simply put into place as shown in figure 2 and the grips brought together until the proper deflection is obtained. The tension in the wire is then read from the other dial, which gives the value directly in pounds.



In any instrument of this type there are two possible sources of error. On account of the inherent stiffness of the larger wires a force is necessary to deflect them even if they are under no tensile load. If the wire is short and held in a rigid framework the tension in it is increased, in the development of the required deflection. This is evident when one considers that there is a slight increase of length of the deflected cable over its original length.

The correction for both of these errors may be found by calculation or preferably by calibration of the instrument. Fortunately, the corrections for both are of such a nature that they are easily made when a constant deflection of the wire is used.

The error caused by the actual lengthening of the wire is usually small. The resulting increase in the total load depends upon the sectional area of the wire and its total length. It may be expressed by the formula $p = \frac{60{,}000A}{L}$ in which p is the increase in the total load



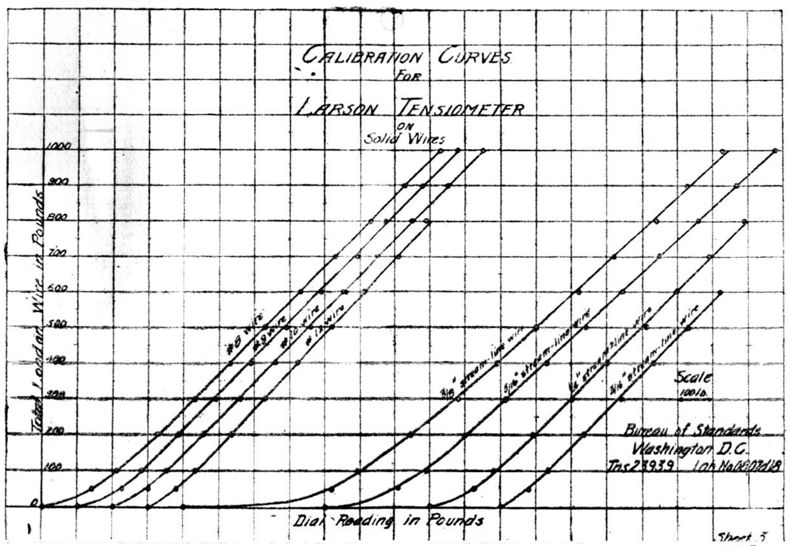
CALIBRATION CURVES
FOR
LARSON TENSIOMETER
ON
NON-FLEXIBLE CABLE
Total Load on Cable in Pounds
Dial Reading in Pounds
Cable #1
Cable #2
Scale
100 lb
Bureau of Standards
Washington D C
Sheet 2

Fig 2

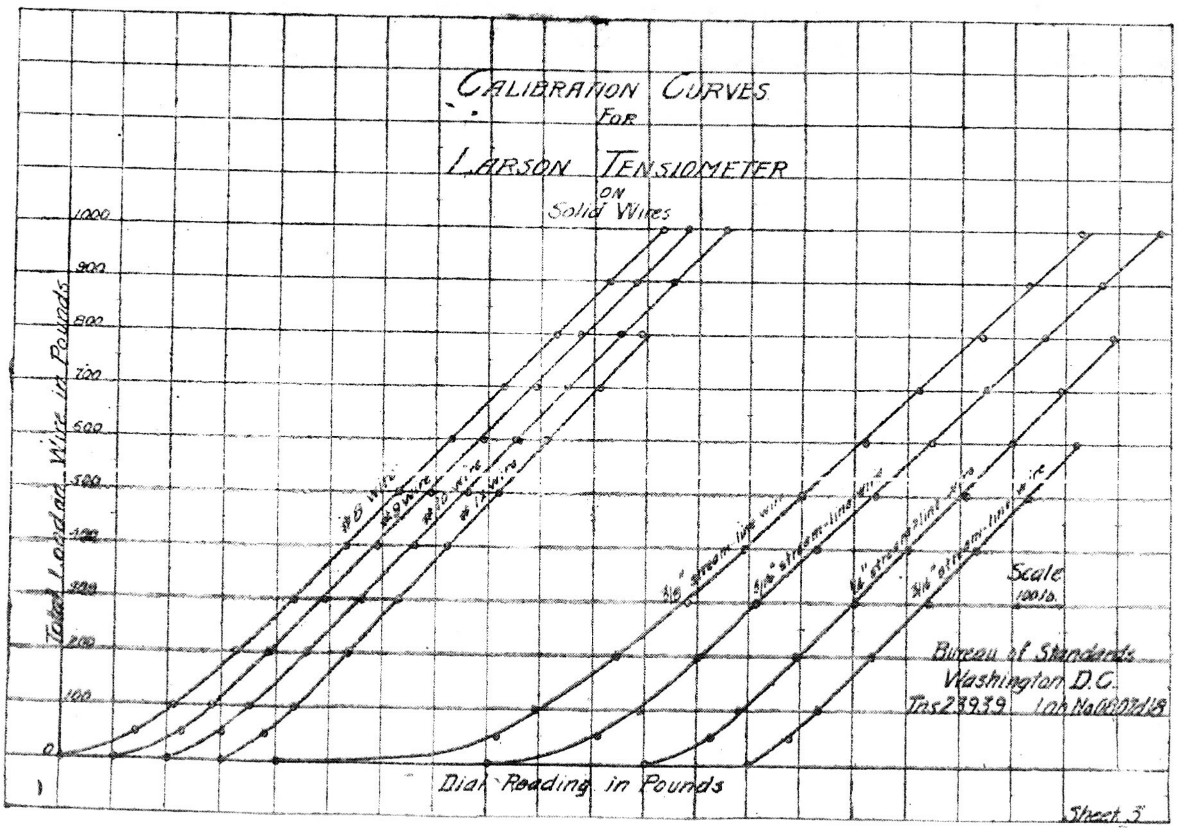
in pounds due to the deflection of the wire; A, the sectional area of the wire in square inches; and L, the total length of the wire in inches. If the error is computed by means of this formula for the conditions met in practice, it will be found to be small. It should also be remembered that the formula assumes that the wires are held rigidly at their ends when the instrument is applied. Any yielding of the structure to which the wire is attached will further reduce the error, so that it appears reasonable to neglect this error for airplane work.

The error due to the stiffness or beam action of the wire is more serious. Although it is negligible for wires of small diameter, a correction is required for large cables and wires. Any theoretical discussion of the magnitude of this error involves the section modulus of the wire and the amount of end constraint acting at the supports.

Aside from the unknown section modulus of the cables it is evident that the amount of end restraint varies with the amount of tensile load on the cable. With no load the cable probably acts as a simple beam and approaches a fixed ended condition with the increase in tensile loading. A calculation of the beam action is therefore impracticable and the only satisfactory method of finding the correction to be applied is to calibrate the instrument for the various sizes of wires and cables upon which it is to be used. Calibration curves have been obtained for most of the sizes of solid airplane wires of both circular and streamline section. Similar curves are available for all sizes of cable in use on airplanes.



To obtain these curves the cable or wire was suspended from a beam and the desired amount of load applied by the use of dead weights, thus insuring a constant load on the wire and the elimination of all sources of error except that of the beam action of the wire or cable. Various increments of load were used depending upon the ultimate strength of the wire, but in all cases a sufficient number of readings were taken to determine the curve. The calibration curves for all the wires and cables tested are shown on the accompanying curve sheets. The actual loads are plotted as ordinates and the indicated loads or the dial readings as abscissae. Since the same scales have been used for ordinates and abscissae, the curves should be straight lines having a slope of 45 degrees to the vertical if the indicated load equals the actual load. An examination of the curves shows that the beam action causes less error for the low tensile loads than for the higher loads. Also the curves for the small cables practically coincide with a 45-degree line, but those for the larger cables and for all solid wires show that the indicated


CALIBRATION CURVES
FOR
LARSON TENSIOMETER
ON
Solid Wires
Total Load on Wire in Pounds
1000
900
800
700
600
500
400
300
200
100
0
#8 Wire
#9 Wire
#10 Wire
#11 Wire
Scale
100 lb.
Bureau of Standards
Washington D.C.
Dial Reading in Pounds
Sheet 3

load exceeds the actual load. However, in most cases the slope of the curves is approximately 45 degrees for loads of over 200 pounds. It is thus possible to make a constant correction equal to the horizontal distance from the curve to a 45-degree line passing through the origin. On a curve which does not have a 45-degree slope, a constant may still be used without serious error provided it is taken from the curve at the working load of the cable. In case this working load exceeds 1,000 pounds, the maximum load applied, the constant should be the correction for 1,000 pounds.

This instrument can therefore be adjusted to read correctly for a perfectly flexible wire of great length or for any particular wire of given length and diameter.

The correction constants obtained experimentally vary for nonflexible cables from 20 pounds for $\frac{5}{32}$ inch to about 550 pounds for $\frac{3}{8}$ inch cables; from 20 pounds for No. 12 (0.08081 inch) to 130 pounds for No. 8 (0.1285 inch solid wire of circular section, and from 40 pounds for $\frac{3}{16}$ inch streamline wire to 575 pounds for $\frac{3}{8}$ inch streamline wire.

Experimental work upon the larger cables shows that a considerable variation in the indicated reading at any load may be expected on cables over $\frac{1}{4}$ inch in diameter. In the case of $\frac{3}{8}$ inch nonflexible cables this variation may be as much as 100 pounds, but when it is considered that such a cable has a breaking strength of 15,000 pounds the error is seen to be less than 1 per cent.

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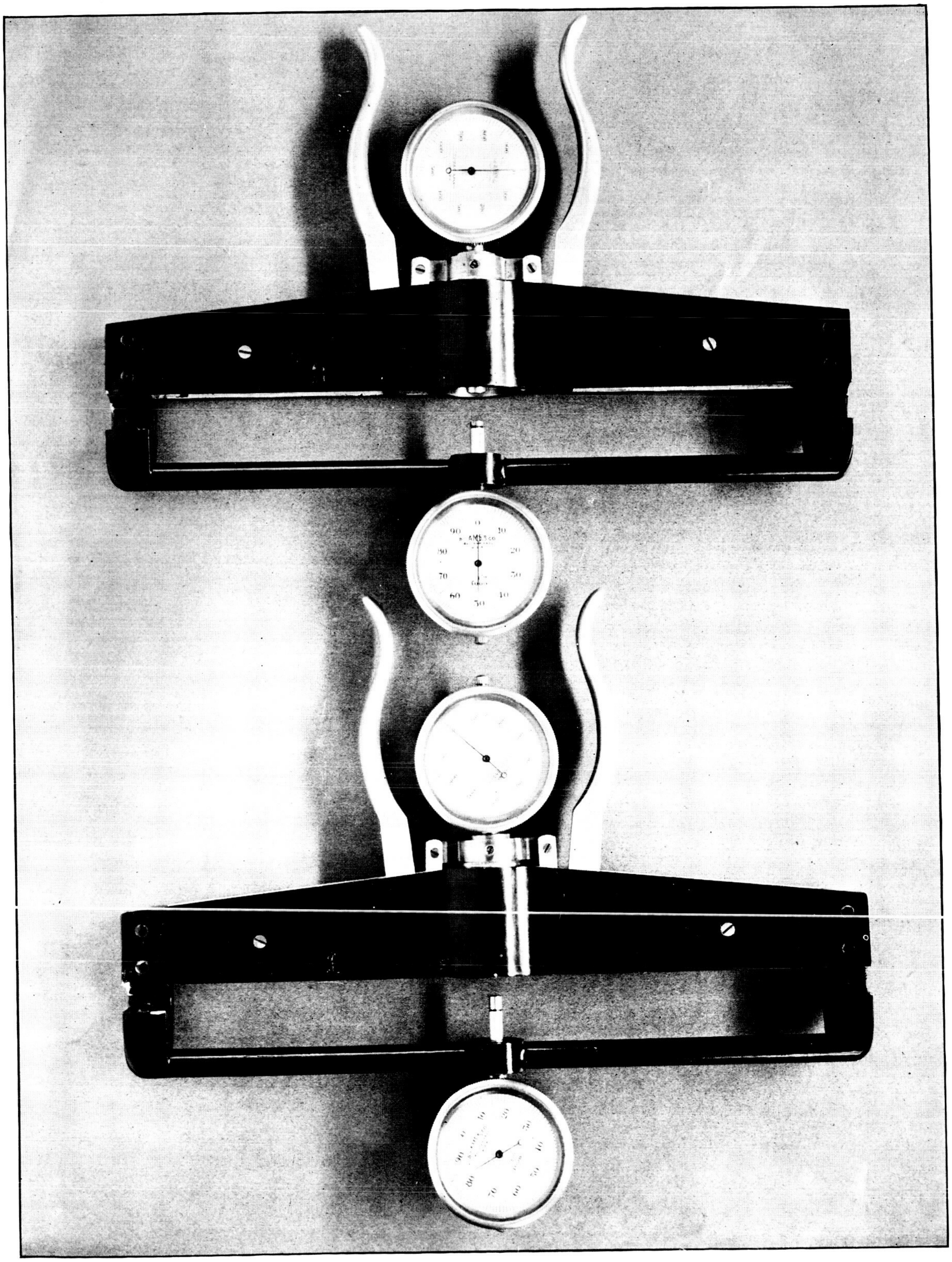

FIG. 1.

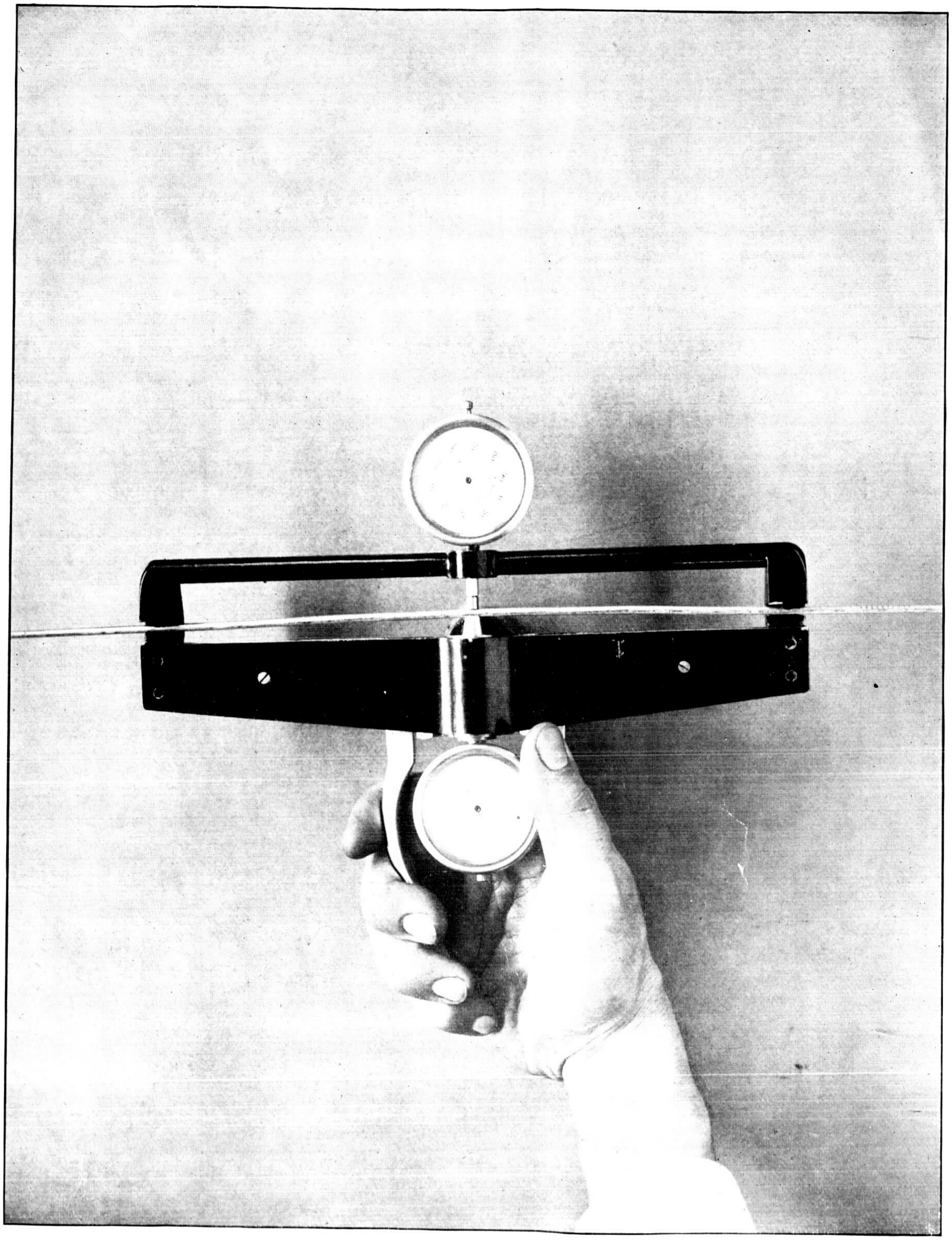

FIG. 2.